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HEAT TRANSPORATION BY HOT WATER PIPE-LINES AT 90 C (LE TRANSPOR--ETC(U)
MAR 77 J M BOURGUET, H FISCHER, L LANCAL

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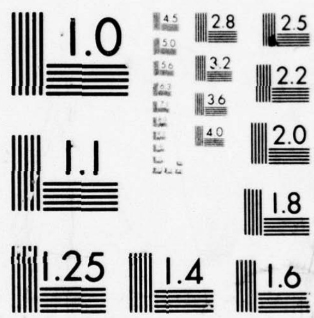

MICROCOPY RESOLUTION TEST CHART
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CRREL

Draft Translation 576
March 1977

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HEAT TRANSPORTATION BY HOT WATER PIPELINES AT 90°C

J.M. Bourguet

CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

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This report describes the possibility of transporting heat produced by Nuclear Power Plants for urban heating distribution systems by means of water at 90°C.

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FRANCE

HEAT TRANSPORTATION BY HOT WATER PIPE-LINES AT 90 °C

Paris TECHNIP ENERGIE INDUSTRIE in French 22 Sep 76

[Paper by J. M. Bourguet, H. Fischer, and L. Lancal, from a conference on "The Production and Utilization of Low and Intermediate Temperature Heat of Nuclear Origin"]

[Text] The Authors

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Heiner Fischer is responsible for studies on the storage of hot water and for problems in the production of geothermal power at Technip Energie Industrie (TEI).

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Louis Lancel is a project engineer at TEI, responsible for problems in energy conservation and solar energy.

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Heat Transportation by Hot Water Networks at 90 °C

Hot water is a remarkable heat reservoir: 1 kg of water stores 1 Kcal for a temperature increase of 1 °C. By comparison, 1 kg of steam (at 150 °C and atmospheric pressure) with a volume of 1.9 m^3, stores only 0.4 Kcal, and one liter of gravel weighing 2.5 kg, only 0.5 Kcal.

This property has been exploited for a long time, to transport over medium distances the heat produced by urban heating plants.

However, the supply-return loop temperatures of 109 °C/70 °C for the low pressure system, and of 180 °C/90 °C for the high pressure one, correspond to economic optima which are obsolete, concerned as they were with low energy costs and unrelated to that which we know today. Moreover, these choices also resulted from the assumption that only heat would be produced, without production of noble power (electricity) which could have been obtained simultaneously.

The increased price of fossil fuels and the need that they be paid in foreign currencies, have led many specialists to reexamine the use of energy for maximum extraction in forms compatible with the needs of the country.

The studies conducted abroad during the last two years are so numerous, and the conferences held on this topic so frequent, that no doubt can remain about the major interest devoted to the combined production of heat and electricity, as well as to the recovery of residual heat in order to satisfy the needs of low level thermal energy.

Today's joint SFEN ANS workshop is one demonstration of France's interest in the topic, which has also been the objective of the Leroy Commission of the French Ministry of Industry.

Notable landmarks are the report of 1 June 1976 of the Brussels Commission of European Communities [1] on rational energy use; the law being discussed in Denmark to impose the joint production of heat and power in fossil fuel or nuclear plants, and urban heating by hot water; numerous Swiss, German, Swedish, and other studies; and so on.

More recently, the United States have started MIUS (Modular Integrated Utility Systems) studies [2], whose favorable conclusions have been reported in the Journal of Engineering for Power of July 1976 [3], bringing hot water grist to the mills of those who support the joint production of heat and power, and the long distance transportation of heat energy at low temperature by hot water at a temperature slightly below 100 °C.

Selection of a Logical Transportation Temperature

Why select a temperature of 90 °C?

First, because it is close to that of existing urban heating networks, and in any case, because it corresponds to the maximum water temperature which is authorized for introduction into buildings and houses [4].

Second, especially because this temperature appears to correspond to an economical optimum. Its production in a thermoelectric plant causes a slight loss of electricity production, of about 0.15 Kwh per metric therm of produced heat (0.13 therms electricity/1 therm heat). The long distance transportation of water at 90 °C can be achieved economically in insulated pipes simply buried in the ground, and requiring neither expansion joints, nor anchoring.

Its eventual storage, which would allow the heat producer to supply continuously while the consumer would draw only according to his needs, can be achieved in open storage facilities with no effective pressure.

And last, it appears that the national needs for heat energy at a temperature lower than 100 °C corresponds to a very high percentage of the primary energy consumed.

The long distance transportation of heat energy in the form of hot water is more economical as the quantity of water transported is higher, and as the temperature difference between the supply and the return is greater.

If the temperature difference is such that the water can be returned to a stream, heat transportation by a single pipe would lead to metric therm prices at the distribution station as shown in figure 1.

Figure 1. Possible values of a hot water therm transported over long distances (single pipe).

Key:
1. Price per metric therm CF = centime of French Franc = 0, 01FF
2. 42,500 inhabitants
3. H: Winter (6 months)
4. E: Summer (6 months)
5. HT price March 1975
6. Water flow rate 3 m/s
7. February 1976 Revision 0

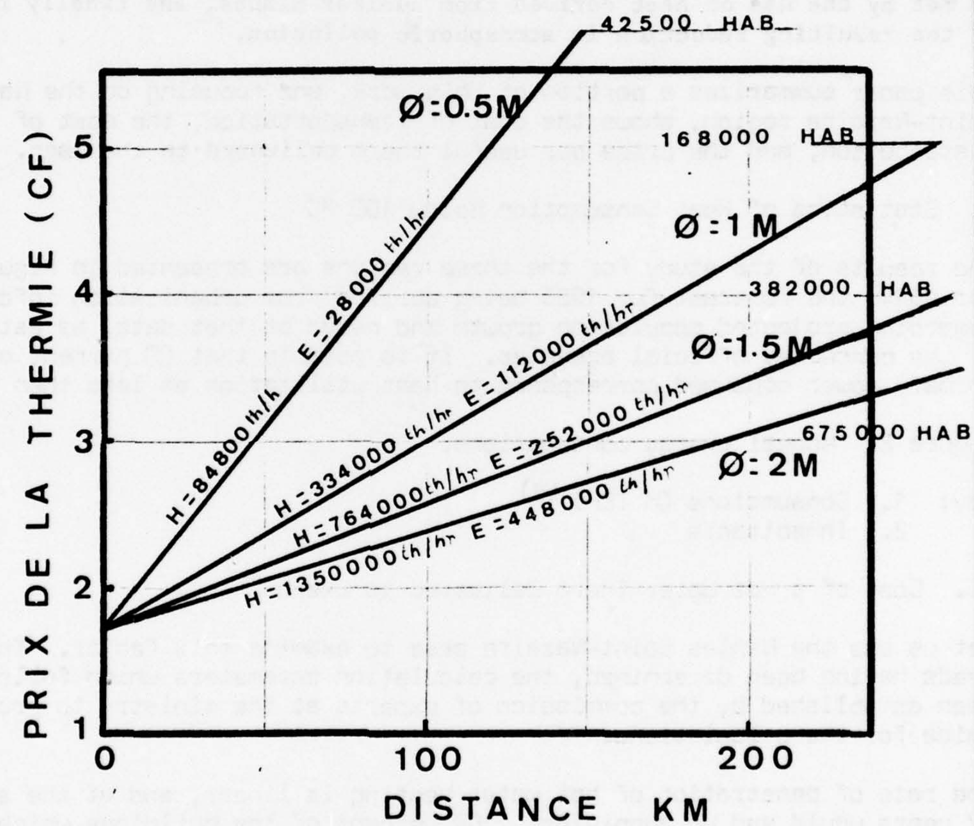
For cost translation assume that US \$1 ≅ 4.8 F. Franc
H.T means (without added value taxes)

FIGURE n° 1

VALEURS POSSIBLES DE LA THERMIE

EAU CHAUDE TRANSPORTEE A GRANDE

DISTANCE (1 SEUL TUYAU)



H: HIVER (6 MOIS)
E: ETE (6 MOIS)

PRIX HT MARS 75

VITESSE DE L'EAU 3 M/S

P: 10 BARS T: 90°C ΔT: 40°C

FEV 76 REV O

The potential energy savings available in the joint production of heat and power, and in the recovery of industrial thermal waste, are accompanied by the possibility of a major reduction in the wastes which pollute the environment: heat in rivers or the atmosphere, toxic combustion products, sulfurous products.

All these combined factors have led the Ministry for the Quality of Life and the Environment, in 1975-1976, to commission a study on this subject by the French Engineering company TECHNIP, for three typical French regions: Lyon, Nantes Saint-Nazaire, and Colmar Mulhouse.

The ministry asked for a statistical estimate of the consumption of heat energy at less than 100 °C, then to estimate how these needs could be met by the use of heat derived from nuclear plants, and finally for an estimate of the resulting reduction in atmospheric pollution.

This paper summarizes a portion of this work, and focusing on the Nantes Saint-Nazaire region, shows the cost of transportation, the cost of distribution, and the price per useful therm delivered to the user.

I. Statistics of Heat Consumption Below 100 °C

The results of the study for the three regions are presented in figure 2 for 1974, the forecast for 1985 being derived from urbanization information regarding projected population growth and needs at that date, as established by the concerned official agencies. It is notable that 50 percent of the primary power consumed corresponds to heat utilization at less than 100 °C.

Figure 2. Annual energy consumptions.

Key: 1. Consumtions (M TEP) (*)
2. Inhabitants

II. Cost of a Hot Water Therm Delivered to Users

Let us use the Nantes Saint-Nazaire case to examine this factor. The heat needs having been determined, the calculation parameters which follow have been established by the commission of experts at the ministry to provide a guide for the calculations.

The rate of penetration of hot water heating is linear, and at the end of 12 years would end up supplying: 100 percent of the buildings which would be built during this period, 80 percent of the existing collectives, and 50 percent of other housing. This, in zones which would have a sufficiently high density of thermal needs to justify the corresponding investments.

TEP - means tons equivalent petroleum = 10,000 metric therms
M TEP = 10^6 TEP

Attention when reading French numbers
3,023 = 3.023,00 in US script

FIGURE n° 2

CONSOMMATIONS D'ÉNERGIE ANNUELLES

	POPULATION 1976	CONSOMMATIONS (M TEP)			
		1974		1985	
	(HAB.)	TOTAL	< 100°C	TOTAL	< 100°C
LYON	1 087 384	3,023	1,439	4,000	1,800
NANTES	458 428	0,640	0,325	0,800	0,408
SAINT-NAZAIRE	175 725	0,273	0,148	0,326	0,208
COLMAR	83 430	0,230	0,091	0,338	0,106
MULHOUSE	218 730	0,613	0,273	0,773	0,296

FEVR. 76 REV.0

Zones consuming 25 Kth/h/km^2 are in all cases suitable for installation; below that, the situation must be carefully examined, in particular for single major users located in sparse zones (hospitals, universities, and so on).

The use of such statistical factors will certainly not lead to a final conclusion, but does make it possible to determine if the project has a good chance of being profitable; if the conclusion is positive, a second stage will enable a detailed study of the problem, together with local collectivities and heat distribution contractors.

By respecting the constraints of the experts, and by limiting the distribution to zones with a concentration of thermal needs of 25 Kth/h/km^2, the population percentages indicated in figure 3 would be candidates for connection to the hot water network.

Figure 3. Population of urban centers under study (1975).

Key:
1. Urban center
2. Total population
3. Population connected
4. Percentage connected

For the Nantes and Saint-Nazaire regions, the resulting networks would be those shown in figures 4 and 5.

Figure 4. Diagram of a possible network (Nantes).

Key:
1. Estimated population for the urban area in 1985: 500,000
2. Connected power: 360 Kth/hr (22 percent of total need)
3. Network length: about 90 km
4. Average diameter: 146 mm
5. Base producer: 140 Kth/hr
6. Peak producer: 140 Kth/hr

Figure 5. Diagram of a possible network (Saint-Nazaire).

Key:
1. Estimated population for the urban area in 1985: 205,500
2. Connected power: 130 Kth/hr (18 percent of total need)
3. Network length: 32 km

Technical Considerations in Network Determination

Transportation Collectors

The studies were based on the following specifications for the long distance transportation collectors:

Supply temperature: 90 °C
Return temperature: 60 °C
Maximum network pressure: 10 bars effective

FIGURE n° 3

POPULATION DES AGGLOMERATIONS ETUDIEES (1975)

AGGLOMERATION	LYON	NANTES	SAINT-NAZAIRE	MULHOUSE	COLMAR
POPULATION TOTALE	1100000	458500	175500	219000	83500
POPULATION RACCORDEE	291000	101700	31000	56000	29100
POURCENTAGE RACCORDE	26 %	22 %	18 %	26 %	35 %

FEV 76 REV 0

FIGURE n° 4

SCHÉMA DE PRINCIPE D'UN RÉSEAU POSSIBLE (NANTES . POPULATION ESTIMEE DE L'AGGLOMERATION EN 1985 : 600000 -)

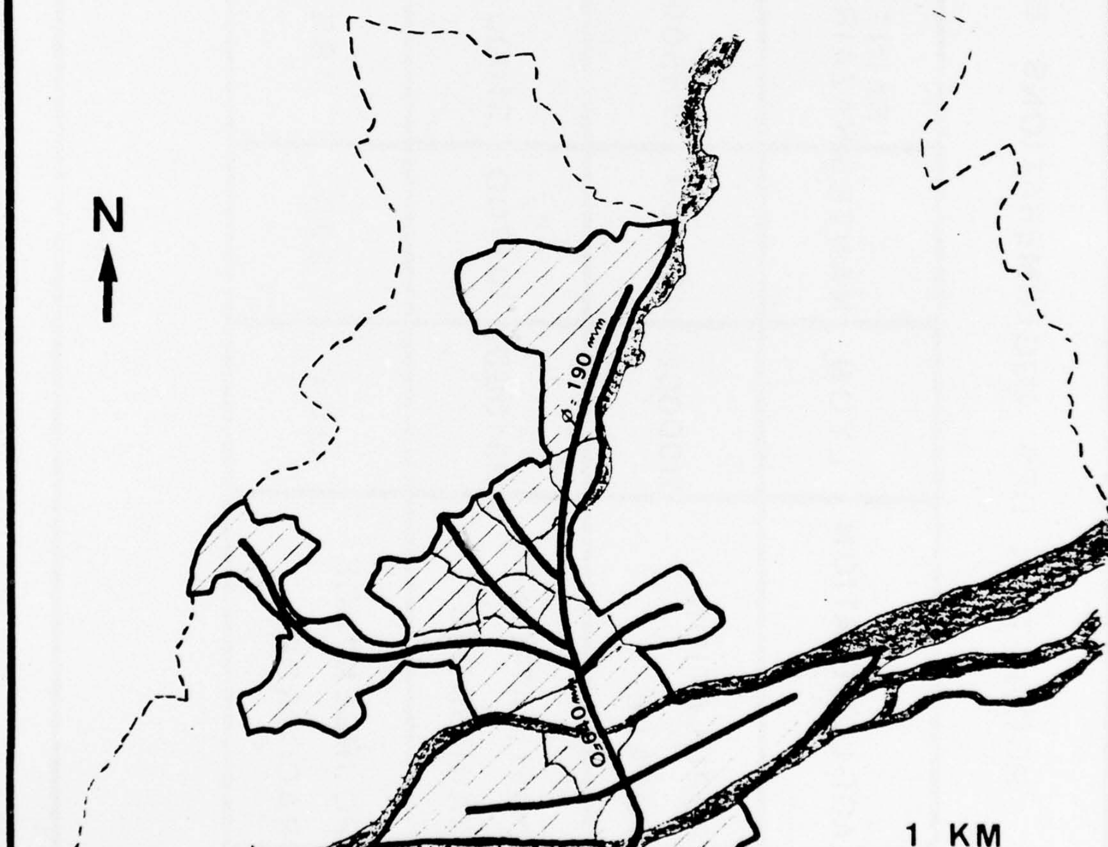
PUISSANCE RACCORDEE **360 KTH/HR** (22 % DES BESOINS TOTAUX)

LONGUEUR DU RESEAU **90 KM** ENVIRON

Ø MOYEN **146 MM**

1 : CENTRALE DE BASE **140 KTH/HR**

2 : CENTRALE DE POINTE **140 KTH/HR**



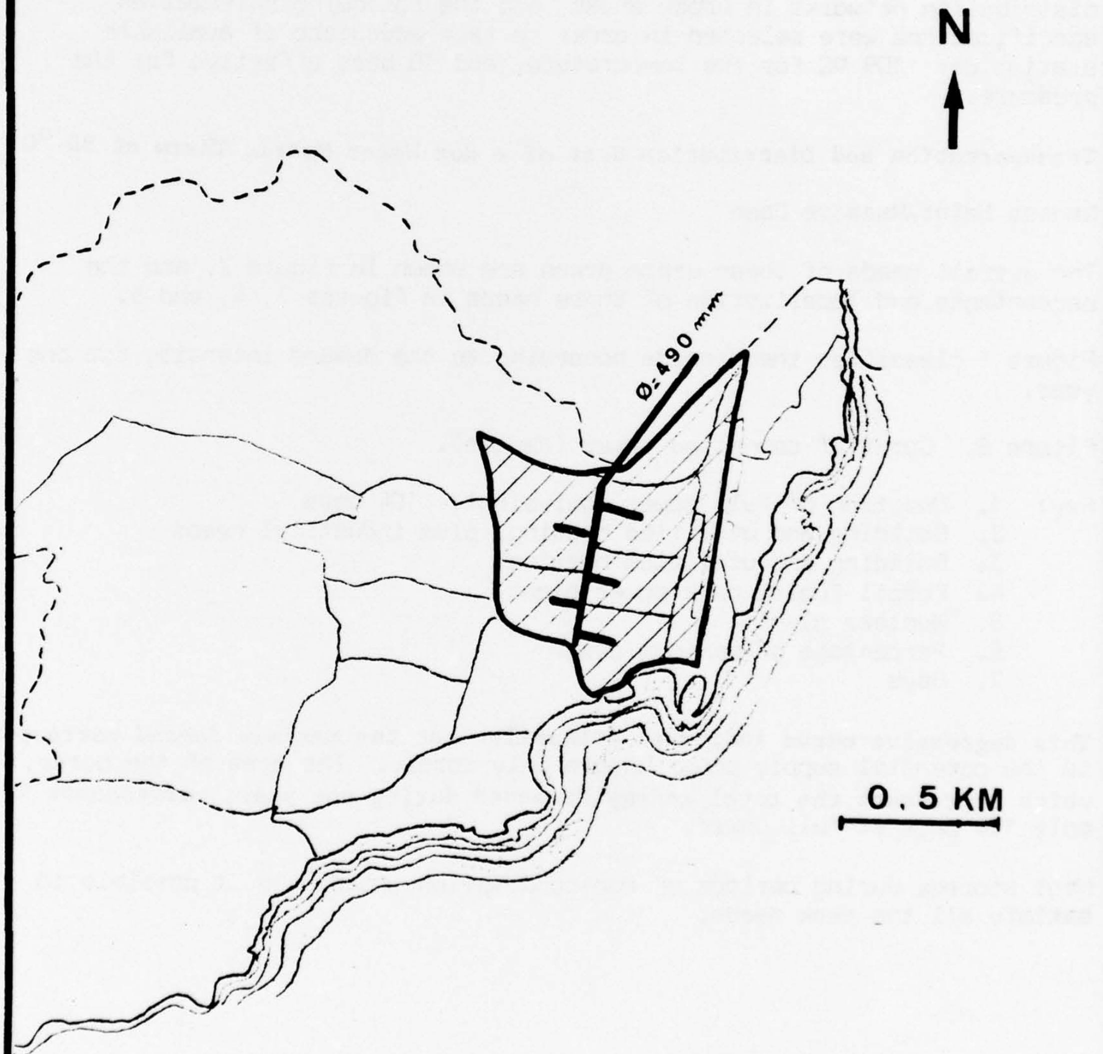
FEV 76 REV 0

FIGURE n° 5

SCHEMA DE PRINCIPE D'UN RESEAU POSSIBLE (S^T-NAZAIRE .POPULATION ESTIMEE DE L'AGGLOMERATION EN 1985 : 205500 -)

PUISSANCE RACCORDEE **130 KTH/HR** (18 % DES BESOINS TOTAUX)

LONGUEUR DU RESEAU **32 KM**



FEV 76 REV 0

The temperatures indicated are those for the coldest days of the year; they decrease rapidly outside these periods, so that the average drew-off temperature at the nuclear power plant is of the order of 70 °C, corresponding to a loss of 0.11 kWh/therm of heat produced (0.095 th electricity/th heating). The return temperatures take into account the fact that past practices in urban heating lead to returns of 70 °C, and that a certain amount of time will be needed to reduce them. Indeed, in order to increase the capacity of a network it is desirable to reduce the return temperature and thereby increase the thermal spread.

A flow rate of about 2 m/sec has been selected to optimize the water flow in the network.

Distribution Networks

The classic formula of insulated pipes in a concrete duct was chosen for distribution networks in urban areas, and the following calculation specifications were selected in order to take advantage of available statistics: 109 °C for the temperature, and 10 bars effective for the pressure.

Transportation and Distribution Cost of a Hot Water Metric Therm at 90 °C

Nantes Saint-Nazaire Case

The overall needs of these urban areas are shown in figure 2, and the percentages and localization of these needs in figures 3, 4, and 5.

Figure 6 classifies these needs according to the demand intensity for one year.

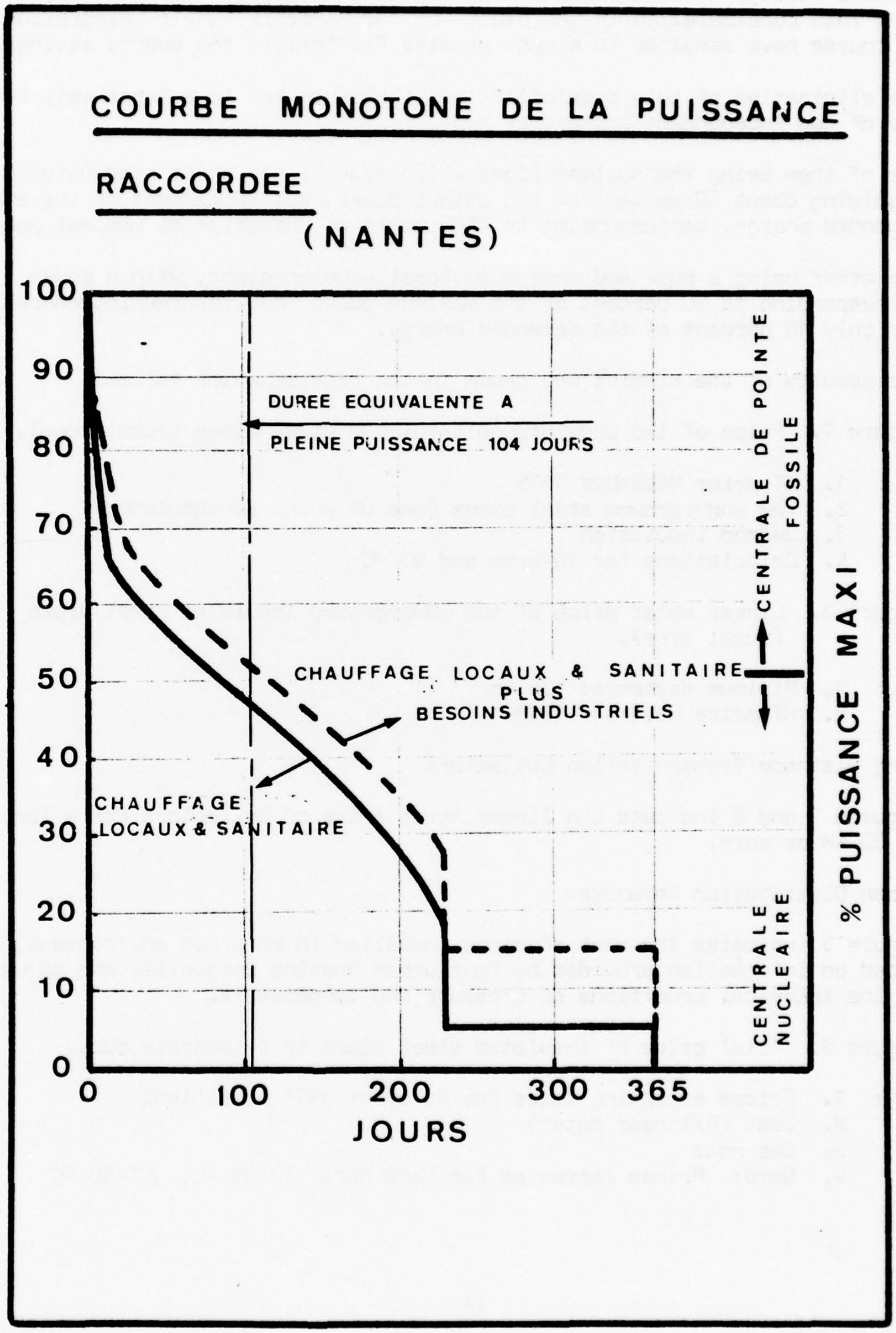
Figure 6. Curve of connected power (Nantes).

Key: 1. Duration of full power equivalent: 104 days
2. Building and utilities heating, plus industrial needs
3. Building and utilities heating
4. Fossil fueled peak power plant
5. Nuclear plant
6. Percentage of maximum power
7. Days

This degressive curve indicates primarily that the maximum demand corresponding to the potential supply power occurs only rarely. The area of the curve, which represents the total energy demanded during one year, corresponds to only 104 days at full power.

Heat storage during periods of non-consumption would make it possible to satisfy all the peak needs.

FIGURE n° 6


COURBE MONOTONE DE LA PUISSANCE
RACCORDEE
(NANTES)
DUREE EQUIVALENTE A
PLEINE PUISSANCE 104 JOURS
CHAUFFAGE LOCAUX & SANITAIRE
PLUS
BESOINS INDUSTRIELS
CHAUFFAGE
LOCAUX & SANITAIRE
CENTRALE DE POINTE
FOSSILE
CENTRALE
NUCLEAIRE
% PUISSANCE MAXI
JOURS
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
365

Because storage techniques are not yet perfected, it was decided not to take them into consideration in the study for the ministry; their integration would of course have resulted in a much greater flexibility and energy savings.

The elimination of this possibility has therefore led to a hypothesis for the use of two independent sources of heat.

One of them being the nuclear plant which assures the basic production by supplying about 50 percent of the output power, but 90 percent of the annual demanded energy, corresponding to 4500 hours of operation at nominal power.

The other being a peak and emergency fossil-fueled plant, with a power corresponding to 50 percent of the maximum power, but intervening annually for only 10 percent of the demanded energy.

The results of the studies are shown in the figures which follow.

Figure 7. Price of two underground insulated steel pipes (rural zone).

Key:
1. HT price November 1975
2. Two underground steel pipes (one of which is insulated)
3. Second insulation
4. Calculations for 10 bars and 90 °C

Figure 8. Linear meter price of two underground insulated steel pipes (rural zone).

Key:
1. Minimum distance: 20 km
2. HT price November 1975

Long Distance Transportation Collectors

Figures 7 and 8 indicate the linear meter price of collectors for a length of 20 km or more.

Urban Distribution Networks

Figure 9 indicates the cost of pipes installed in an urban environment, based on information provided by four urban heating companies, and adjusted to the technical conditions of pressure and temperature.

Figure 9. Total price of insulated steel pipes in a concrete duct.

Key:
1. Prices excepting taxes for November 1975 conditions
2. Cost (F/linear meter)
3. See note
4. Note: Prices corrected for P=10 bars, T=109 °C, ΔT=50 °C

FIGURE n° 7

PRIX DE 2 TUYAUX ACIER CALORIFUGÉS ENTERRÉS

(ZONE RURALE)

PRIX HT NOV 75

ϕ MM	300	500	1000	1500	2000
2 TUYAUX ACIER ENTERRÉS (DONT 1 CALORIFUGÉ)	900	1681	3445	5637	8901
DEUXIEME CALORIFUGE	200	355	612	828	910
TOTAL F/ML	1100	2036	4057	6465	9811

CALCULS POUR 10 BARS 90°C

FEV 76 REV O

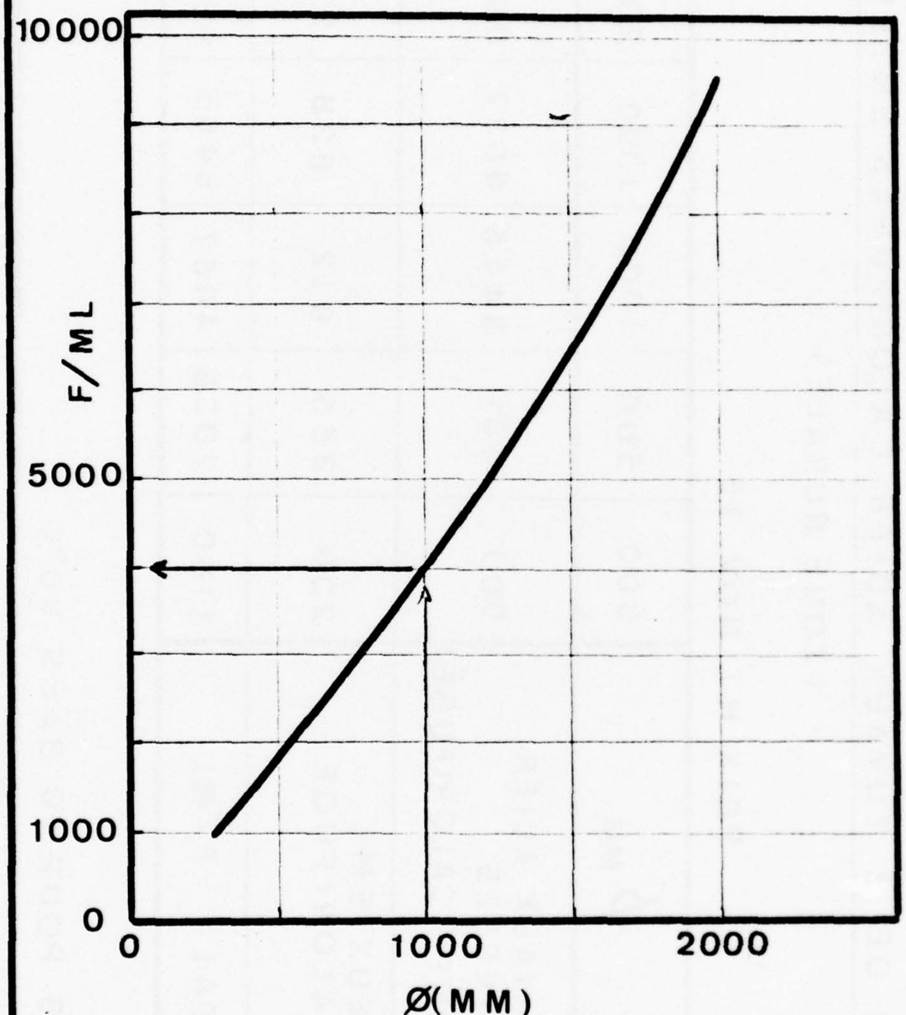
FIGURE n° 8

PRIX AU METRE LINEAIRE DE 2 TUYAUX

ACIER, CALORIFUGÉS, ENTERRÉS

(ZONE RURALE)

DISTANCE MINI 20 KM

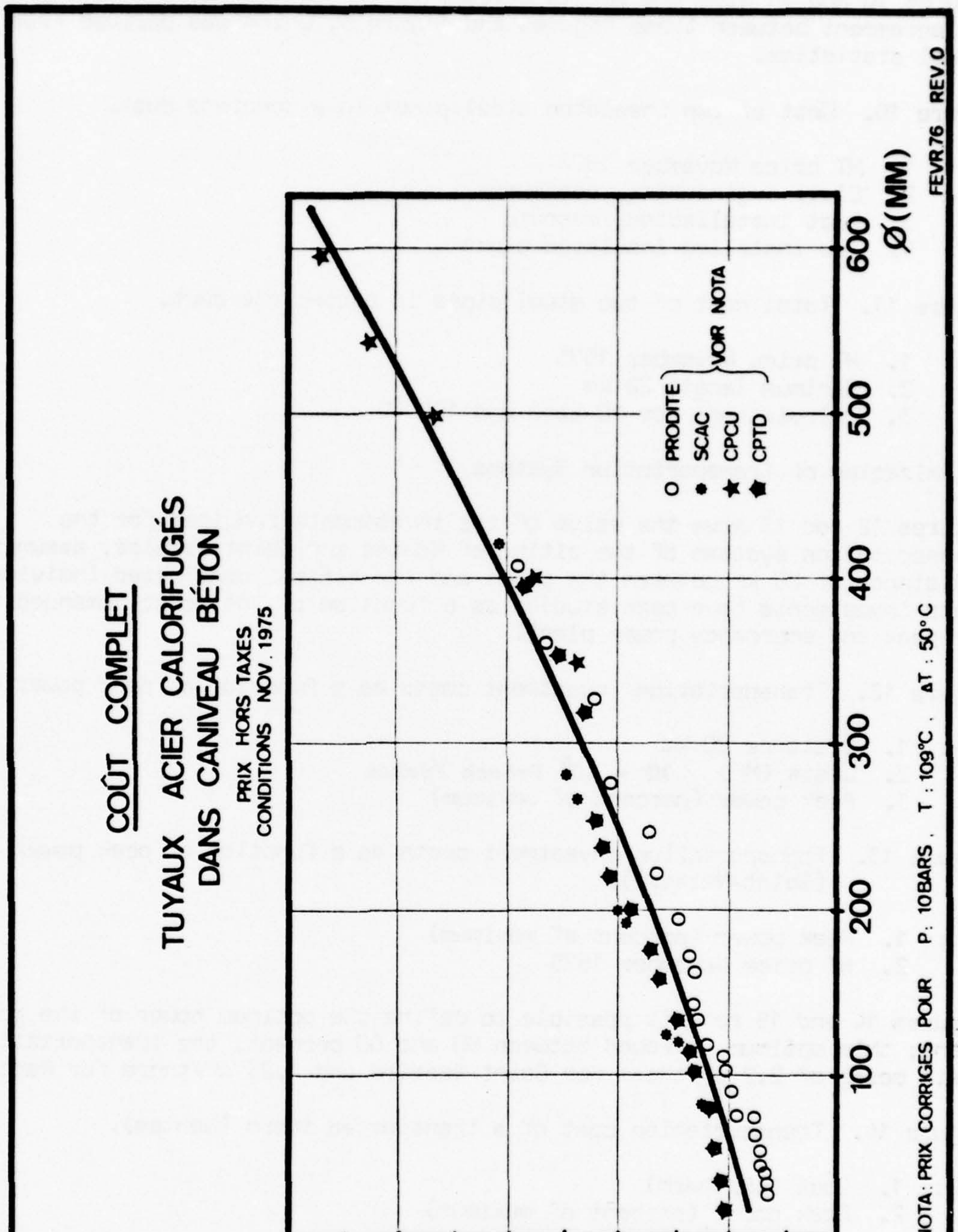


PRIX HT NOV 75

P : 10 BARS T : 90°C

FEV 76 REV O

FIGURE n° 9


COÛT COMPLET
TUYAUX ACIER CALORIFUGÉS
DANS CANIVEAU BÉTON
PRIX HORS TAXES
CONDITIONS NOV. 1975
COÛT
(F/M$_{LIN}$)
4000
3000
2000
1000
100
200
300
400
500
600
Ø (MM)
O PRODITE
• SCAC
★ CPCU
CPTD
VOIR NOTA
NOTA: PRIX CORRIGES POUR P: 10BARS, T: 109°C, ΔT: 50°C
FEVR.76 REV.0

Figures 10 and 11 give the values calculated for the ministry study; observe the agreement between these figures and figure 9, which was derived from actual statistics.

Figure 10. Cost of two insulated steel pipes in a concrete duct.

Key: 1. HT price November 1975
2. Civil engineering, earthwork
3. Duct installation, masonry
4. Two installed insulated pipes

Figure 11. Total cost of two steel pipes in a concrete duct.

Key: 1. HT price November 1975
2. Minimum length 20 km
3. Calculations for 10 bars and 109 °C

Optimization of Transportation Systems

Figures 12 and 13 give the value of the investments required for the transportation systems of the cities of Nantes and Saint-Nazaire, assuming a distance of 20 km between the plant and the cities, considered individually. These investments have been studied as a function of the power demanded from the peak and emergency power plant.

Figure 12. Transportation investment costs as a function of peak power (Nantes).

Key: 1. Distance 20 km
2. Costs (MF) MF = 10^6 French Francs
3. Peak power (percent of maximum)

Figure 13. Transportation investment costs as a function of peak power (Saint-Nazaire).

Key: 1. Peak power (percent of maximum)
2. HT price November 1975

Figures 14 and 15 make it possible to define the optimum power of the peak plant; this optimum is found between 50 and 60 percent, the transportation costs being of 2.2 cF/therm for Saint-Nazaire and 1.26 cF/therm for Nantes.

Figure 14. Transportation cost of a transported therm (Nantes).

Key: 1. Cost (cF/therm)
2. Peak power (percent of maximum)

FIGURE n° 10

COUT DE 2 TUYAUX ACIER CALORIFUGÉS

DANS UN CANIVEAU EN BÉTON

PRIX HT NOV 75

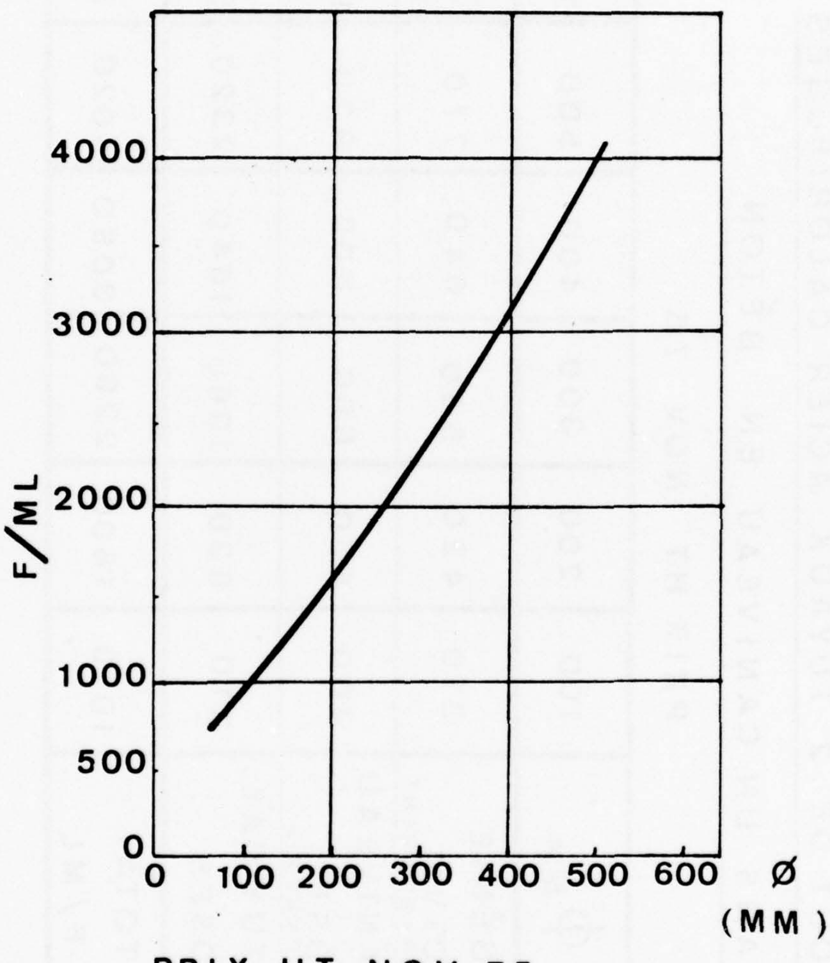
Φ MM	100	200	300	400	500	600
GÉNIE CIVIL TERRASSEMENT	310	420	560	640	770	890
CANIVEAU POSE MAÇONNERIE	400	550	660	800	930	1070
2 TUY. CAL. POSÉS	310	630	1060	1640	2320	3170
TOTAL F/ML	1010	1600	2280	3080	4020	5120

P: 10 BARS T: 109 °C

FEV 76 REV 0

FIGURE n° 11

COÛT GLOBAL DE 2 TUYAUX ACIER DANS UN CANIVEAU EN BÉTON



PRIX HT NOV 75

LONG. MINI 20 KM

CALCULS POUR 10 BARS 109°C

FEV 76 REV O

FIGURE n° 12

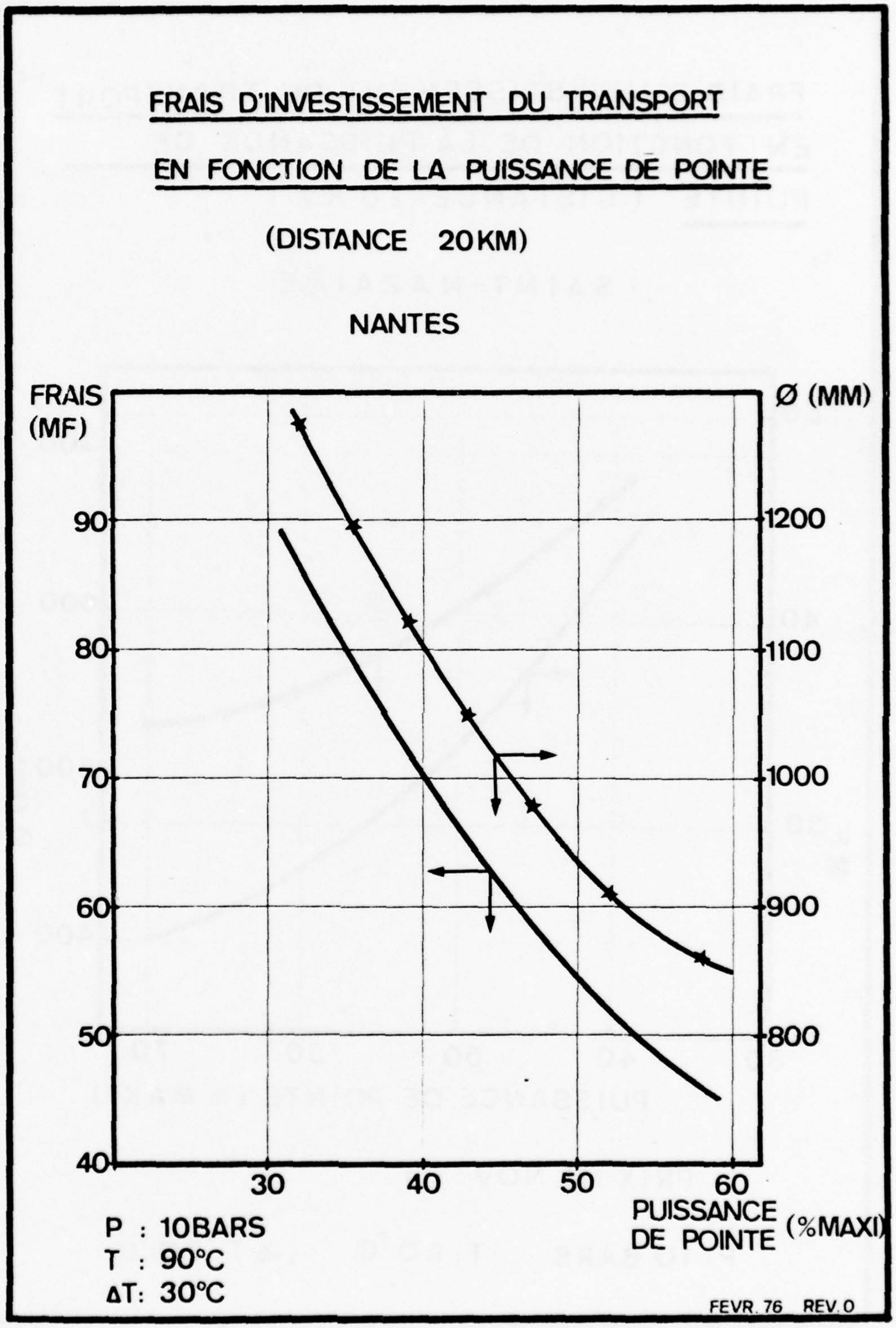
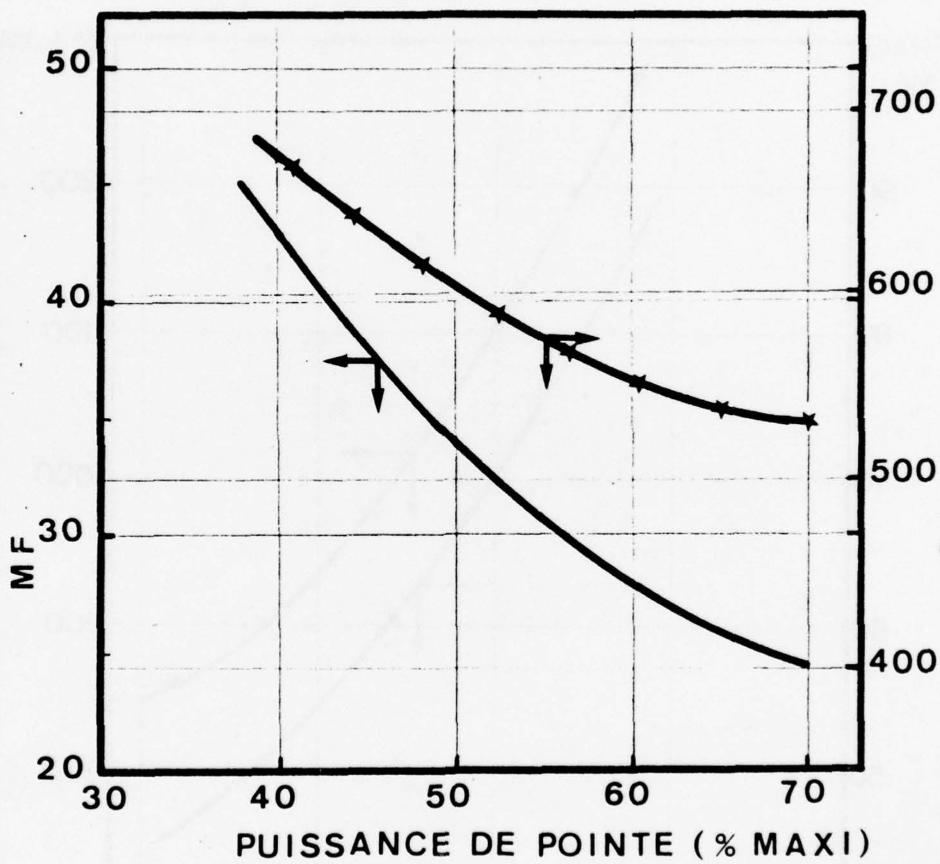

FRAIS D'INVESTISSEMENT DU TRANSPORT
EN FONCTION DE LA PUISSANCE DE POINTE
(DISTANCE 20 KM)
NANTES
FRAIS (MF)
Ø (MM)
90
80
70
60
50
40
1200
1100
1000
900
800
30
40
50
60
PUISSANCE DE POINTE (%MAXI)
P : 10 BARS
T : 90°C
ΔT: 30°C
FEVR. 76 REV. 0

FIGURE n° 13

FRAIS D'INVESTISSEMENT DU TRANSPORT EN FONCTION DE LA PUISSANCE DE POINTE (DISTANCE 20 KM)

SAINT-NAZAIRE



PRIX HT NOV 75

P: 10 BARS T: 90°C ΔT: 30°C

FEV 76 REV O

FIGURE n° 14

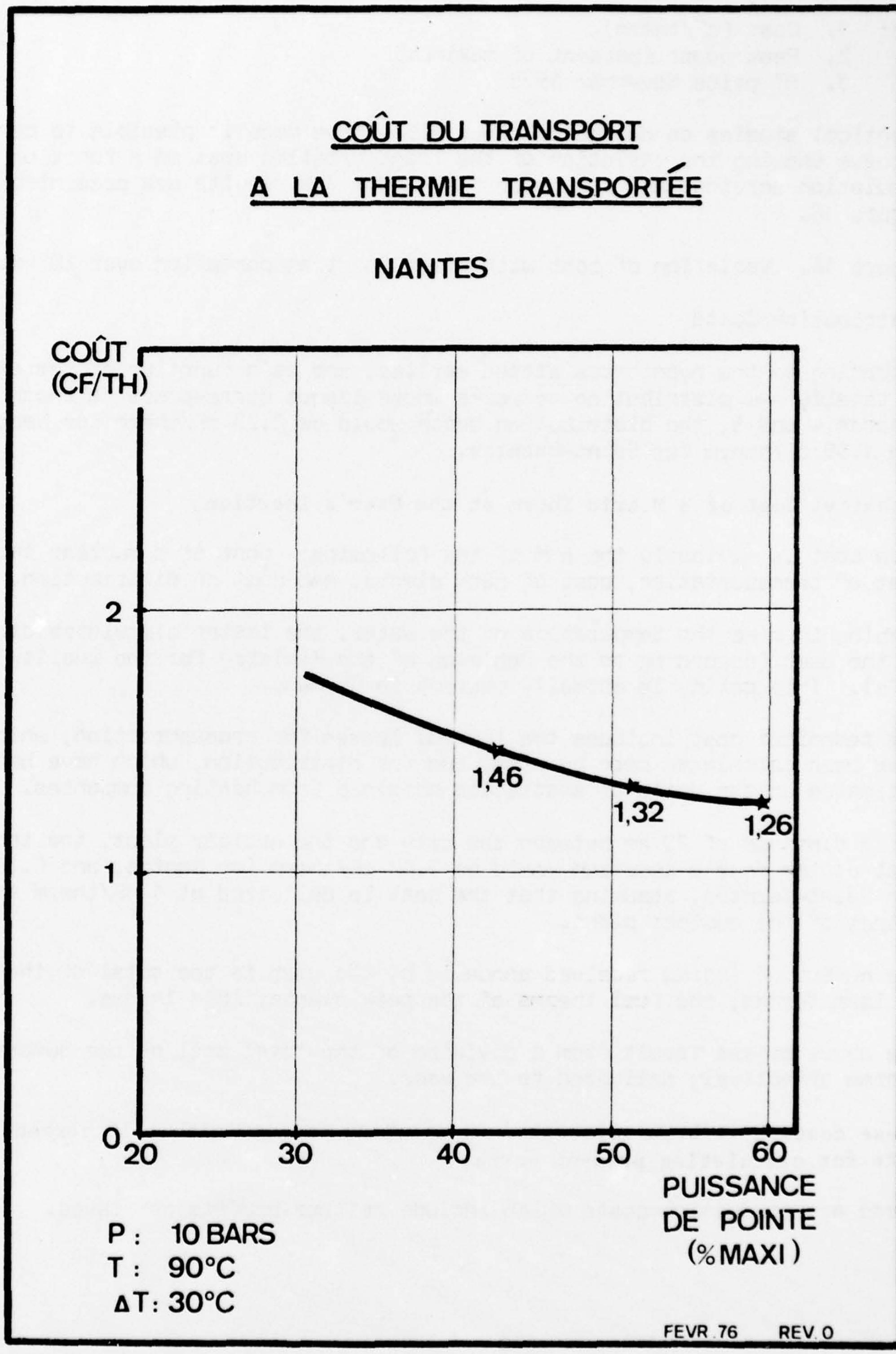

COÛT DU TRANSPORT
A LA THERMIE TRANSPORTÉE
NANTES
COÛT
(CF/TH)
2
1
0
20
30
40
50
60
1,46
1,32
1,26
PUISSANCE
DE POINTE
(%MAXI)
P : 10 BARS
T : 90°C
ΔT: 30°C
FEVR 76
REV 0

Figure 15. **Transportation cost of a transported metric therm (Saint-Nazaire).**

Key: 1. Cost (cF/therm)
2. Peak power (percent of maximum)
3. HT price November 1975

Identical studies conducted at other sites have made it possible to construct a curve showing the variation of the transportation cost as a function of the population serviced and the power demanded. The results are presented in figure 16.

Figure 16. Variation of cost with power for transportation over 20 km.

Distribution Costs

According to the hypotheses stated earlier, and as a function of the expansion of totally new distribution networks whose layout corresponds to those of figures 4 and 5, the distribution costs would be 2.25 cF/therm for Nantes, and 1.99 cF/therm for Saint-Nazaire.

Technical Cost of a Metric Therm at the User's Location

This cost is obviously the sum of the following: cost of a nuclear therm, cost of transportation, cost of peak plants, and cost of distribution.

Keeping in mind the temperature of the water, the latter circulates directly to the user (according to the decision of the Ministry for the Quality of Life). This policy is actually current in Germany.

The technical cost includes the thermal losses for transportation, which have been calculated case by case, and for distribution, which have been estimated on the basis of statistics obtained from heating companies.

For a distance of 20 km between the city and the nuclear plant, the technical cost at the user's location would be 5.62 cF/therm for Nantes, and 6.38 cF/therm for Saint-Nazaire, assuming that the heat is delivered at 1 cF/therm at the output of the nuclear plant.

The number of therms received annually by the user is the total of the nuclear therms, the fuel therms of the peak plants, less losses.

The above prices result from a division of the total cost by the number of therms effectively delivered to the user.

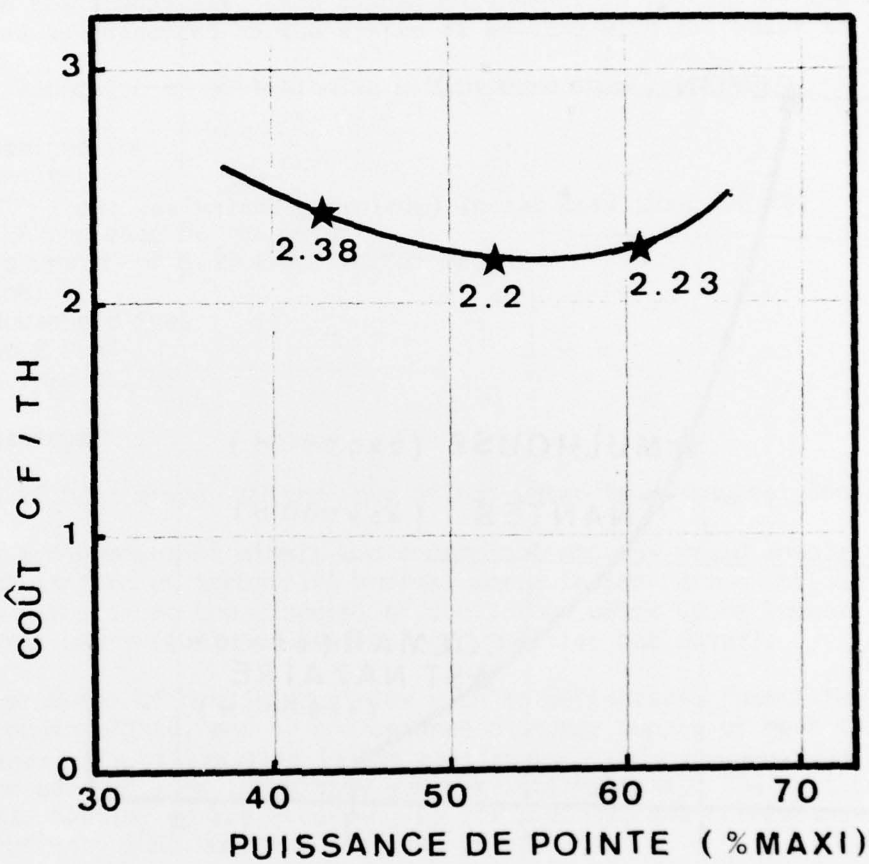
These costs have been calculated in constant francs, with a 10 percent discount rate for calculating present worth.

These are production costs which include neither profits nor taxes.

FIGURE n° 15

COÛT DU TRANSPORT A LA THERMIE TRANSPORTÉE

SAINT-NAZAIRE



PRIX HT NOV 75

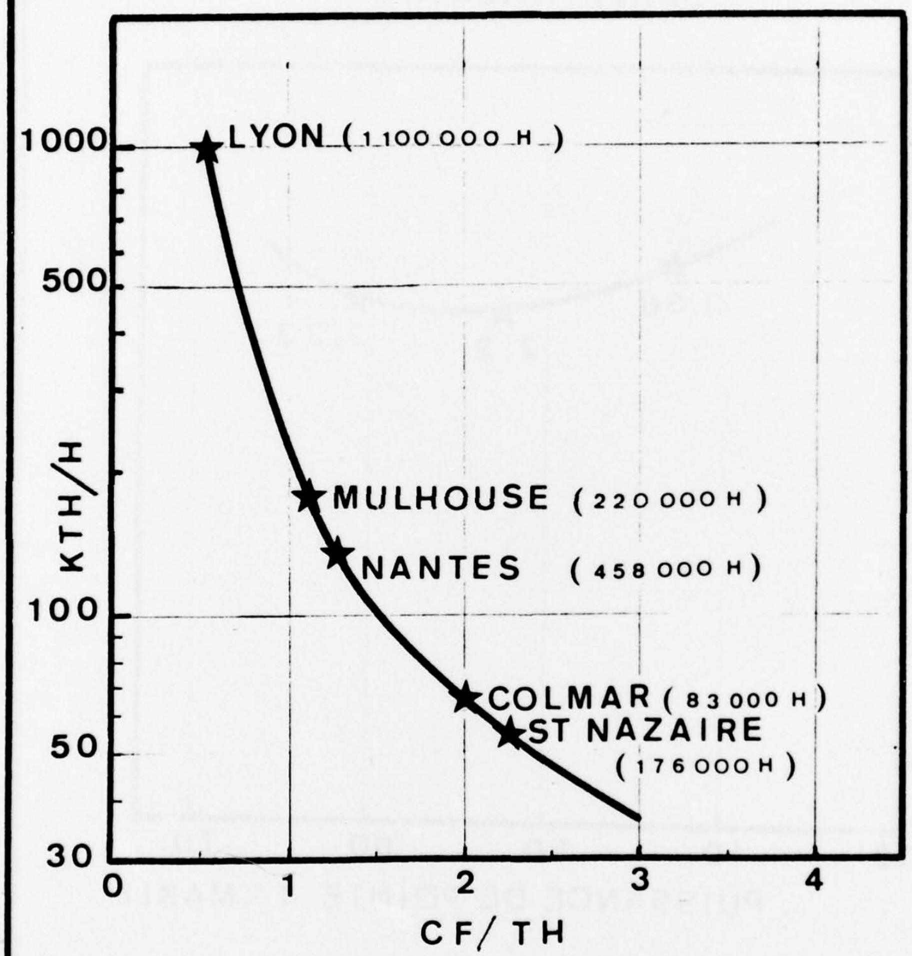
P: 10 BARS T: 90°C ΔT: 30 °C

FEV 76 REV O

FIGURE n° 16

TRANSPORT 20 KM . VARIATION

DU COÛT AVEC LA PUISSANCE



PRIX HT NOV 75

P: 10 BARS T: 90 °C ΔT: 30 °C

FEV 76 REV O

The difference with respect to current prices for urban heating -- namely 9 to 10 cF/therm, exclusive of tax, plus connection taxes -- is thus quite significant, with a generous allowance for uncertainties and errors arising from inaccuracies in details.

It would alone justify continued studies for technical design and market surveys, not even mentioning the fact that similar results have been obtained for other studied regions.

Reduction of Environmental Thermal and Chemical Pollution

Without delving on the help which the joint production of power and heat would provide during drought periods (i.e., Summer 1976), an examination of figure 17 dramatically discloses its effect on the reduction of sulfur discharges into the atmosphere, even though only about 25 percent of the demand is considered as connected to the system of heating with hot water at 90 °C.

Figure 17. Reduction of pollution by a hot water carrier at 90 °C.

Key:
1. Designation
2. Units
3. TEP (tons equivalent petroleum) (total less than 100 °C)
4. TEP replaced by hot water
5. Reduction of discharged sulfur weight
6. Coal
7. Household fuel
8. No 2 fuel
9. Burned sulfur

Hot Water Storage

The storage of heat energy in the form of hot water is of capital importance.

Indeed, the achievement of simple and economical storage would enable the maximum exploitation of industrial thermal waste in the form of hot water, in order to place it at the disposal of continuous users (some industries) or intermitent users (building heating and utilities hot water).

For if the producer of heat (industries such as refineries, fossil-fueled or nuclear power plants, and so on) assures a steady supply of heat through its operations, its utilization is not continuous. Only process heat needs on the part of some industries are not intermittent. The heat demand for household heating varies according to the seasons, and corresponds to an average of only 2000 hours of the peak power.

The storage of hot water (according to figure 18) between a continuous producing plant and seasonal users would thus make it possible to match heat production to fluctuating demand.

FIGURE n° 17

RÉDUCTION DE LA POLLUTION PAR LE VECTEUR EAU CHAUDE A 90° C

DÉSIGNATION	UNITÉ	LYON	NANTES	SAINT NAZAIRE	COLMAR	MULHOUSE
T.E.P (TOTAL MOINS DE 100°C)	TEP/AN	1439000	324800	148000	91000	273000
T.E.P REMPLACÉES PAR L'EAU CHAUDE	TEP/AN	425000	102000	34000	42500	102000
	RÉDUCTION DU POIDS DE SOUFRE REJETÉ					
CHARBON	T/AN	573	136	36	121	245
FUEL DOMESTIQUE	T/AN	2160	466	155	233	597
FUEL N° 2	T/AN	3045	542	182	271	696
SOUFRE BRÛLÉ	T/AN	5778	1144	373	625	1538
SO_4H_2	T/AN	17680	3500	1141	1912	4706
TOTAL SO_4H_2	T/AN	28939				

FEV 76 REV O

Figure 18. Hot water storage. Operating principle.

Key: 1. Producer
2. Storage
3. Consumer

This storage would also make it possible to smooth out the differences which arise daily between heat production and consumption. Moreover, the storage is considered as a safety precaution for the heat supply in case of production stoppage.

One example would be the stoppage of a generating plant, whether fossil-fueled or nuclear, of the more special case of solar heating.

Hot water storage would thus make it possible to store the production of heat, which occurs mainly in summer, for recovery during the winter (figure 19). In addition, it would insure a supply when very little or no sun is shining.

Figure 19. Correlation of storage with solar energy.

Key: 1. Energy
2. Energy needs (heating and household hot water)
3. Useful solar energy
4. Stored energy
5. Months

As we indicated at the beginning, the storage must be simple and economical; considering the many storage techniques available, and beginning with the well known metal storage tanks, it appears opportune to consider the investment cost for their installation.

Indeed, the storage capacity must be large: several tens or hundreds of thousand cubic meters, and even several millions of cubic meters. It is obvious that for these dimensions, economic solutions can be found only in natural environments.

TECHNIP has studied two types of natural environment storage capacities, the selection of which will depend upon the geological structure of the land:

If the structure offers a permeable terrain (sand, gravel), limited in depth by an impermeable layer, one can envisage a storage of the type shown in figure 20;

In other geological formations, the storage would be in an excavated structure (artificial lake) such as shown in figure 21.

FIGURE n° 18

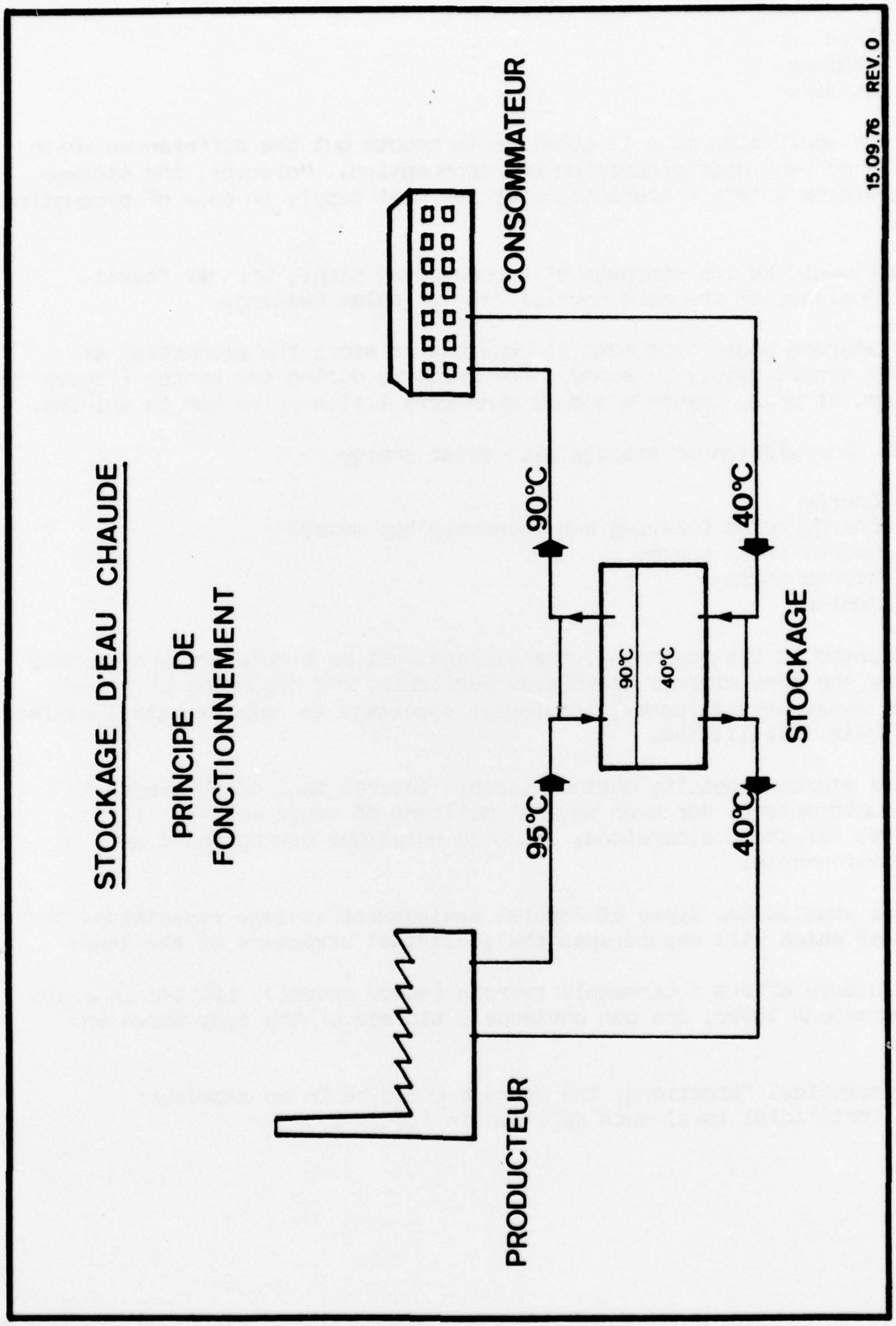

STOCKAGE D'EAU CHAUDE
PRINCIPE DE FONCTIONNEMENT
CONSOMMATEUR
PRODUCTEUR
STOCKAGE
95°C
90°C
40°C
40°C
90°C
40°C
15.09.76 REV.0

FIGURE n° 19

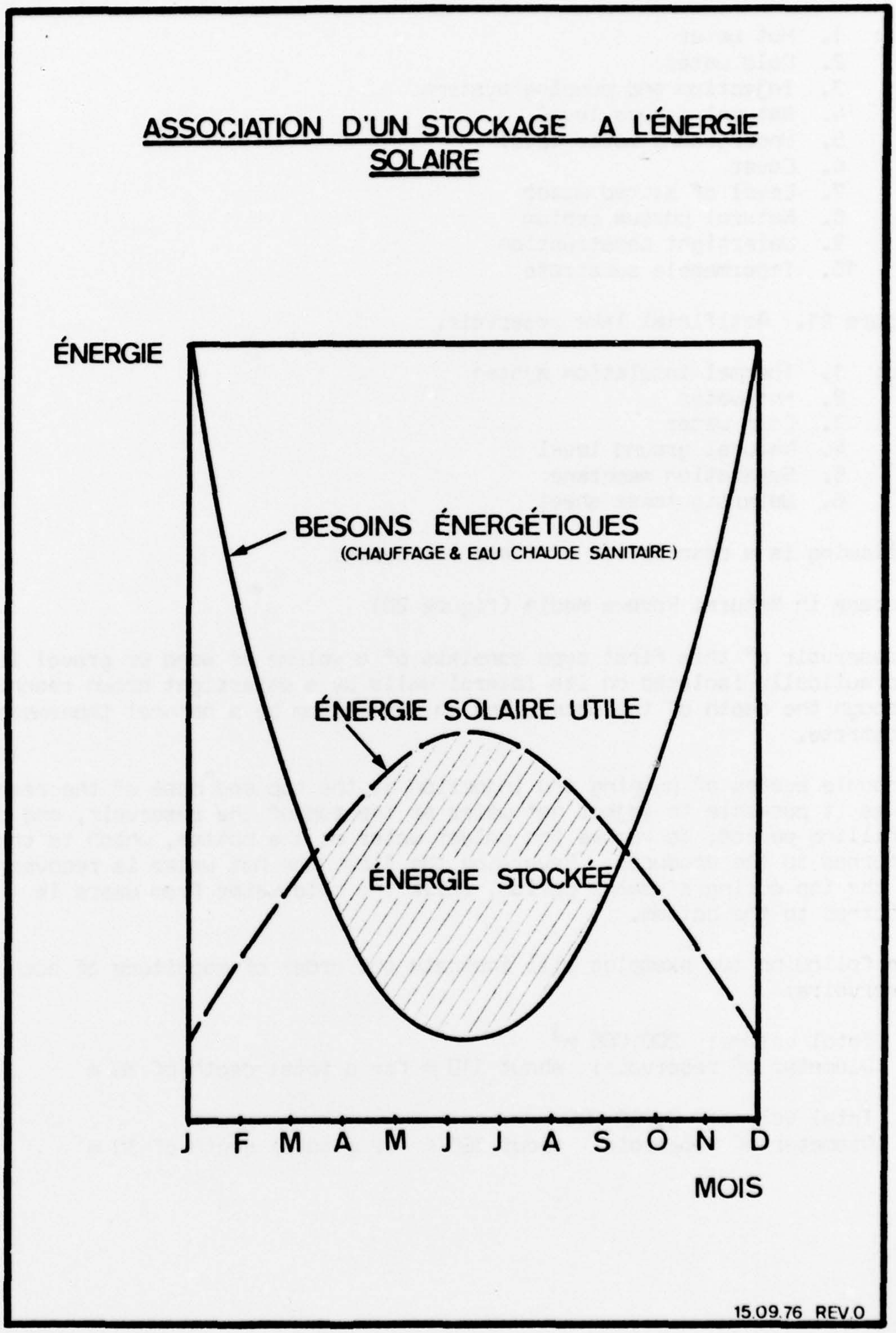

ASSOCIATION D'UN STOCKAGE A L'ÉNERGIE SOLAIRE
ÉNERGIE
BESOINS ÉNERGÉTIQUES
(CHAUFFAGE & EAU CHAUDE SANITAIRE)
ÉNERGIE SOLAIRE UTILE
ÉNERGIE STOCKÉE
J F M A M J J A S O N D
MOIS
15.09.76 REV.0

Figure 20. Storage in a natural porous environment.

Key:
1. Hot water
2. Cold water
3. Injection and pumping systems
4. Natural ground level
5. Underground water level
6. Cover
7. Level of stored water
8. Natural porous medium
9. Watertight construction
10. Impermeable substrate

Figure 21. Artificial lake reservoir.

Key:
1. Thermal insulation system
2. Hot water
3. Cold water
4. Natural ground level
5. Separation membrane
6. Watertightness sheet

Following is a description of these two types:

Storage in Natural Porous Media (figure 20)

A reservoir of this first type consists of a volume of sand or gravel layers, hydraulically isolated on its lateral walls by a watertight crown reaching through the depth of the water, and on its bottom by a natural impermeable substrate.

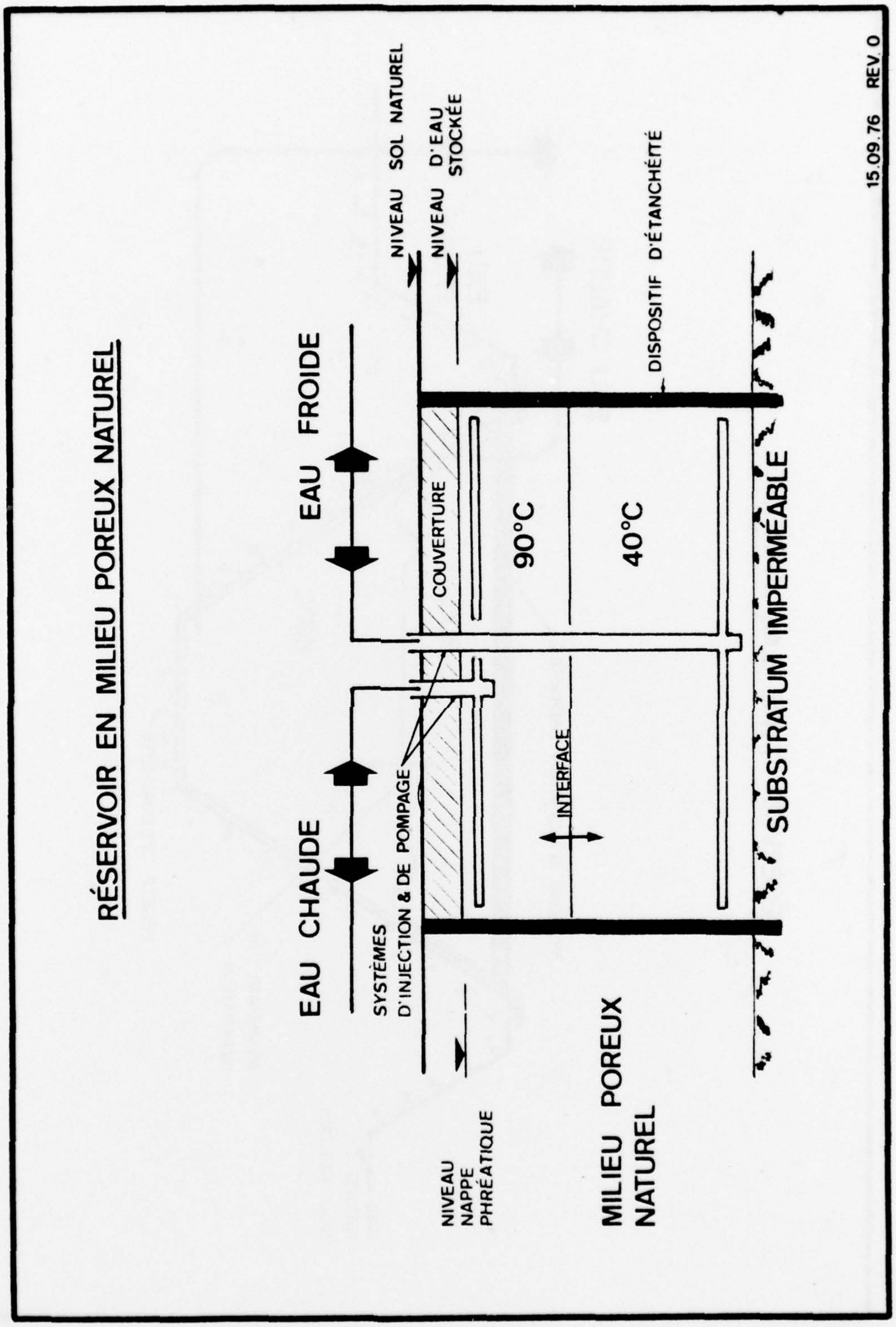
A double system of pumping and injection at the top and base of the reservoir makes it possible to inject hot water at the top of the reservoir, and during a filling period, to remove the colder water at the bottom, which is then returned to the producer. Reversing the flow, the hot water is recovered at the top during a demand period, while the cold water from users is returned to the bottom.

The following two examples will indicate the order of magnitude of such reservoirs:

a) Total volume: 200,000 m^3
   Diameter of reservoir: about 110 m for a total depth of 30 m

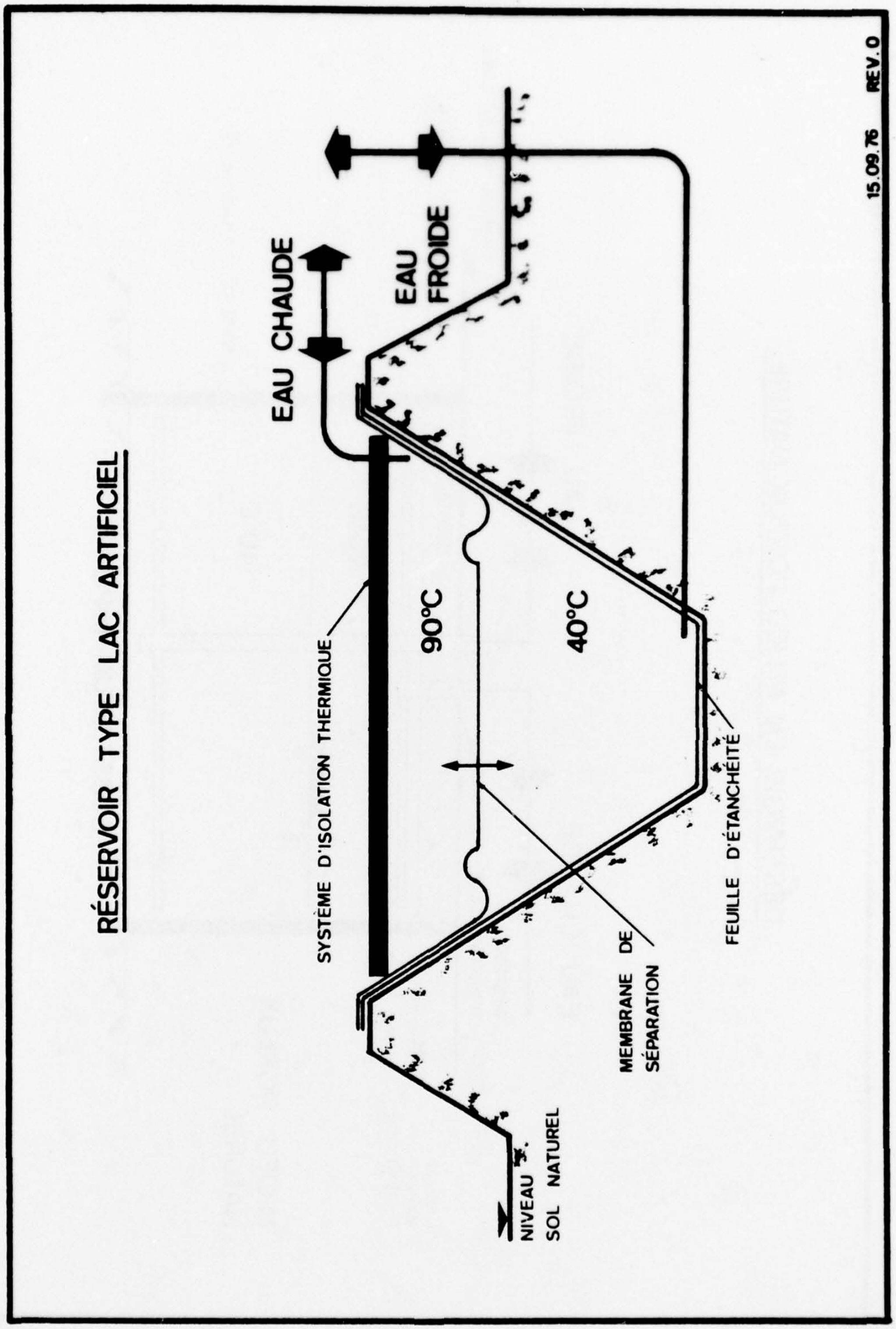
b) Total volume: 2,000,000 m^3
   Diameter of reservoir: about 360 m for a total depth of 30 m

FIGURE n° 20



RÉSERVOIR EN MILIEU POREUX NATUREL
EAU CHAUDE
EAU FROIDE
NIVEAU SOL NATUREL
NIVEAU D'EAU STOCKÉE
SYSTÈMES D'INJECTION & DE POMPAGE
COUVERTURE
90°C
40°C
INTERFACE
DISPOSITIF D'ÉTANCHÉITÉ
NIVEAU NAPPE PHRÉATIQUE
MILIEU POREUX NATUREL
SUBSTRATUM IMPERMÉABLE
15.09.76
REV. 0

FIGURE n° 21


RÉSERVOIR TYPE LAC ARTIFICIEL
EAU CHAUDE
EAU FROIDE
SYSTÈME D'ISOLATION THERMIQUE
90°C
40°C
MEMBRANE DE SÉPARATION
FEUILLE D'ÉTANCHÉITÉ
NIVEAU SOL NATUREL
15.09.76
REV.0

Storage in an Artificial Lake (figure 21)

The reservoir consists of an excavation, part of whose depth is below the natural ground level, and part above, the earth removed from the underground portion being used to build the levee of the upper portion.

Watertightness is insured by a plastic sheet placed on the bottom and sides; the surface of the water is insulated through appropriate means.

As for the preceding method, this reservoir is used at constant fill volume, the hot water being stored above the cold water.

For a nominal volume of 200,000 m^3 and a depth of 40 m, the surface area of the water will be about 12,000 m^2.

For a storage of 2,000,000 m^3, the surface area will be about 70,000 m^2.

A comparison of these two types of storage leads to the following comments:

The use of the first method requires a suitable geological formation which is not found everywhere; no such restriction exists for the second method;

On the other hand, the first method of storage has a clear advantage for environmental protection, since the area of such reservoirs is reusable for agricultural purposes, for instance, even though its area is relatively smell;

And let us not overlook the safety aspect. Storage in an artifical lake can indeed present certain dangers for the surrounding population, through the presence of water at 90-95 °C, retained by a levee. Access to this storage would obviously have to be strictly forbiden.

At this point we should observe that the storage of heat energy is also under study in other countries.

In West Germany, for instance, a vast program of research and development is being pursued, during which tests on prototypes will be performed in the near future.

Sweden also appears to have performed tests in a natural lake, whose central portion was isolated by an immersed vertical plastic wall.

It would be desirable to undertake such research on an international scale, or at least European scale; if this were so, the Commission of European Communities would encourage these projects by supporting research and development.

Let us point out that at the national French level, the DGRST would be the one to underwrite these studies and the eventual installation of a prototype.

(1)

DGRST (Direction Generale Recherche Scientifique et Technique)

BIBLIOGRAPHY

1. Commission of European Communities, "The Rational Use of Energy." Final report of group G: "Transformations in Electric Generation Plants," Brussels, 1 June 1976.

2. Gerald S. Leighton, ASHRAE JOURNAL, "Modular Integrated Utility System Program," pages 43-46, December 1973.

3. A. LLeri, G. M. Reistad, and W. E. Schmisseur, JOURNAL OF ENGINEERING FOR POWER, "Urban Utilization of Waste Energy from Thermal-Electric Power Plants," pages 309-319, July 1976.

4. Unified Technical Document (DTU) No 65: "Temporary Specifications for Central Heating Installations in Buildings," Chapter IV, paragraph 4.11, page 12:

   The maximum temperature (t °C) of the water in the output pipes of the generator(s) is called the maximum temperature of normal operation; in all cases it will be equal to at most 90 °C. (October 1965)